THERMAL CUSHION AND DEVICE COMPRISING SUCH A CUSHION

Field of the invention

The invention relates to thermal cushions and to their use.

State of the art

The hospital sector and ambulatory medicine are major users of thermal cushions, in particular for external thermal regulation and in order to relieve pain or in various therapies such as for example cryotherapy.

Indeed, it is known that the application of cold can relieve pain (headaches, migraine, toothaches, muscular or inflammatory pains, etc.) or encourage the resorption of hematomas, edemas and the healing of accidental or surgical wounds.

US 3,545,230 proposes a coolant cushion that uses the latent heat of fusion of a solid substance. During this fusion phase, the temperature remains constant. The cushion comprises a layer of insoluble and hydrophilic gel in a sealed and flexible envelope. An inert and flexible substrate (for example fibres or a fabric), immersed in the gel, serves to strengthen the mechanical resistance of the cushion and allows it to take any geometrical form. To give the cushion sufficient flexibility, several layers of gel of very small thickness (barely a few millimetres) are superposed on each other and a flexible and inert film is inserted between the layers of gel. This known cushion has the drawback of being difficult and expensive to produce, its performances are weak and its applications limited.

In document EP 0 123 949, the cryogenic substance of the cushion comprises pieces of gel with a particular structure having an elasticity that is comparable to that of rubber and which do not stick together at the temperature of

cold production. The motion of the pieces of gel relative to each other in the cushion gives the latter the desired flexibility. These known cushions nevertheless have the drawback of requiring an expensive gel and their manufacture is delicate and costly.

United States patent US 3,885,403 suggests to use for the cryogenic substance a gel containing a high proportion of an agent that lowers the freezing point below the normal temperature of use. Glycerine and propylene glycol are proposed for the agent that lowers the freezing point. With this known cushion, the production of cold does not result from the latent heat of fusion but from the gradual reheating of the gel. This known cushion has the property that it is of simple construction and retains good flexibility and suitability to flexible deformation due to the fact that the gel does not go through a solid phase. On the other hand, it has the drawback of a short working life since the production of cold does not result from the latent heat of fusion but from the gradual reheating of the gel. Moreover, the productivity of the cushion (the production of cold or the extraction of calories per unit of time) is not constant but decreases as the gel is reheated, which represents a further drawback for this known cushion.

Document WO 97/11657 describes alveolar panels that are formed of a grid of cells filled with a thermal agent. Between the cells, the panel has rectilinear zones with a low breakpoint that allow to divide it at will (by shearing or tension) into thermal cushions of predetermined sizes depending on the applications for which these cushions are intended. In these alveolar panels, the interstices are the cause of several drawbacks. For one thing, they reduce the thermal capacity of the panel and for another they present an obstacle to homogeneous action of the panel when the latter is applied onto a patient's skin.

Document FR 1 018 835 A describes thermal cushions that comprise a network of compartments with a thermal substance and which are connected to each other by flexible membranes. The network of compartments is enclosed in a flexible envelope forming, together with the compartment walls, a chamber that is filled with a thermal fluid. These known thermal cushions have poor flexibility and are difficult to deform, mainly when the thermal fluid of the envelope is a liquid or a solid substance in the state of particles. They are therefore ill-suited to uniform application on a human or animal limb.

Summary of the invention

The invention aims to overcome the above-mentioned drawbacks of known thermal cushions and to meet the needs of potential users (in particular in a hospital environment) by providing a thermal cushion of a new design that combines excellent flexibility/elasticity with being able to adapt perfectly, even to forms in motion and with a high and lasting calorific value at a more or less constant temperature, whose action is homogeneous (especially when it is used on a part of the human body), whose thickness can be maintained more of less constant during use, whose size and shape are more or less unlimited, that can undergo major variations in pressure without deforming and that, thanks to its above-mentioned properties, can adapt to many different uses, in particular in a hospital environment, without requiring major handling.

As a result, the invention relates to a thermal cushion comprising a network of blocks connected by articulations and separated by interstices, said blocks comprising a thermal substance and said interstices being filled, at least partially, with a deformable thermal substance, said thermal cushion being characterised in that the articulations are selected from

- the elastic solid bodies that are attached to the blocks and thus form at least part of the above-mentioned deformable thermal substance;
- the elastic membranes that are attached to the blocks and put under pressure so that they compress a deformable body present in the interstices, said deformable body thus forming at least part of the deformable thermal substance; and
- the articulations, which are permeable to a fluid present in the interstices, said fluid thus forming at least part of the deformable thermal substance.

The thermal cushion according to the invention is intended to be brought into contact with a physical body with the aim of affecting the heat exchanges of this body with the surrounding environment.

The expression "body" is to be understood in a general sense as referring to a material object. It refers without distinction to a solid, liquid or gaseous body. In the case of a solid body, it may for example be the surface of a solid object or a part of the anatomy of an animal or of a human being. In the case of a liquid body, it may be the surface of a table of a liquid bath. In this application of the invention, the cushion may for instance act as a sealed partition between two different liquids or between a liquid and a surrounding atmosphere, for example the environment. In the case of a gaseous body, it comprises an atmosphere. In this application of the invention, the cushion according to the invention may for instance form a screen between two different atmospheres, for example a hot atmosphere (the atmosphere of an industrial furnace) and an atmosphere at moderate temperature. As a variant, in the case of a liquid or gaseous body, it may possibly be enclosed in a sealed envelope, for example a flexible membrane.

The ambient environment may be a gaseous or liquid environment. In the case of a gaseous environment, it may for instance be atmospheric air, the atmosphere of a heated room, the atmosphere of a refrigerated room (for example a cool store) or the atmosphere of an industrial furnace (non-exhaustive list). In the case where the surrounding environment is a liquid environment, it may for instance be water or an industrial chemical bath.

In the present document, the expression "normal temperature of use" refers to the temperature of the thermal substance of the blocks and/or the interstices when the cushion is used.

In the present document, the term "cushion" refers in a very general sense to any solid and flexible element intended to be brought into contact with the body (as defined above) so as to cover it at least partially or to wrap it entirely or partially. The thermal cushion according to the invention can therefore be adapted in very varied ways depending on the use it is intended for. It may for example take the form of an article of bedding (pillow, cover, mattress), a pocket, a sleeve, an article of clothing or part of an article of clothing, a packaging, a screen or curtain, a covering (non-exhaustive list). It may be made in various modules that can be assembled.

The thermal cushion according to the invention is a cushion which, when it is brought into contact with a body (as in the above definition), at normal temperature of use, causes a transfer of heat between said cushion and said body or contributes to maintaining the temperature of said body more or less constant.

The thermal cushion according to the invention is termed "calorific cushion" or "cryogenic cushion" when its normal temperature of use is different from that of the body with which it is brought into contact, so that a heat transfer

occurs between said cushion and said body. When the heat transfer is occurring naturally in the direction from the body towards the thermal cushion, it is a cryogenic cushion. In the case when the heat transfer occurs in the direction from the thermal cushion to the body, the thermal cushion according to the invention is a calorific cushion.

The thermal cushion according to the invention is termed "isothermic cushion" when its normal temperature of use is more or less equal to that of the body with which it is brought into contact so that there is no heat transfer between said body and the thermal cushion. An isothermic cushion according to the invention then provides the technical function of a calorific insulator by forming an obstacle to the heat transfer between the body and the ambient environment.

The thermal cushion according to the invention comprises a network of blocks between which interstices are provided. The interstices are generally connected to each other.

By definition, each block of the cushion is a solid element. The shape of the blocks of the cushion according to the invention will be detailed later on.

The blocks are assembled in a network. They are moreover spaced so as to form a network of interstices between them. The cushion according to the invention thus comprises an interwoven structure of interstices in an interwoven structure of blocks. The network of blocks generally comprises a single layer or stratum of blocks although a network formed by several layers of superposed blocks is not excluded from the invention.

The blocks of the network are articulated with each other. In other words, the blocks of the network are connected to each other by articulations. Details concerning the articulations will be provided later on.

In the cushion according to the invention, the shapes and sizes of the blocks, the shapes and sizes of the interstices and the choice of the articulations are adapted so that the network of blocks forms a solid structure that is deformable by bending and/or twisting and/or rotation around multiple axes distributed in a three-dimensional space. This particular feature of the cushion according to the invention allows it to easily adapt to virtually any shape of body to which it is applied (for example part of the human or animal anatomy) and to follow its movement.

In the cushion according to the invention, the blocks and the interstices comprise a thermal substance. The thermal substance will be explained later on.

The shapes of the blocks depend on the use of the cushion and are not critical to the definition of the invention. The blocks may for example have a spherical, hemispherical, ovoid, annular, lenticular, conical, truncated conical or polyhedral shape. The blocks may have flat, curved or skewed faces, for example helicoidal, or may comprise an assembly of flat faces and of curved or skewed faces. They may for instance have the shape of little barrels that combine a curved annular face and flat faces at the ends. In general, any shape is acceptable which, associated with the interstices and articulations connecting the blocks, allows the deformation of the cushion as explained above. Polyhedral shapes are generally preferred.

Among the polyhedral shapes, right-angled or pyramidal polyhedrons are preferred. Truncated pyramids are especially recommended. Among right-angled or pyramidal polyhedrons, polyhedrons with triangular, trapezoidal, square, rectangular or octagonal bases are preferred.

In a preferred embodiment of the invention, each block is formed by two truncated pyramids joined along their long bases, for example two triangular, trapezoidal, square or

octagonal truncated pyramids. In this preferred embodiment of the invention, the blocks are advantageously articulated in the geometrical plane of the above-mentioned long bases of the two truncated pyramids.

As explained above, the interstices arranged between the blocks have the function of allowing the motion of these blocks around the articulations that connect them. The shapes of the interstices will depend on various parameters such as the type of deformation desired for the network of blocks (single-axis, double-axis or triple-axis bending, twisting, stretching or combination of two or several of these deformation types), the degree of deformation, the shapes and sizes of the blocks, the articulations used and the arrangement of the articulations between the blocks.

In the thermal cushion according to the invention, the blocks are made of a thermal substance. The thermal substance of the blocks gives its thermal properties to the thermal cushion according to the invention. In the case of a cryogenic cushion, the thermal substance of the blocks is selected from those which, once brought to normal temperature of use and then subjected to cooling, release a large quantity of heat. In the case of a calorific cushion, the thermal substance of the blocks is selected from those which, once brought to normal temperature of use and then heated, pick up a large quantity of heat. In the case of an isothermic cushion, the thermal substance of the blocks is selected from those which block the heat transfer or which, once brought to normal temperature of use, then require a large input of heat in order to change their temperatures. Thermal substances which, at normal temperature of use, have a high specific heat are generally suitable for the three types of cushion according to the invention. These thermal substances are those known and used in technology for their property of

accumulating large quantities of heat and which are found in particular in applications as thermal accumulators.

In the thermal cushion according to the invention, blocks may be entirely made of the thermal substance which is then necessarily solid at normal temperature of use as well as in normal conditions of handling for the thermal cushion. As a variant, blocks may, in addition to the thermal substance, comprise another substance which does not on its own perform the function of the thermal substance as defined above. The thermal substance may be identical in all the blocks or may differ depending from the block. Moreover, each block may comprise a single thermal substance or a mixture of two or several thermal substances. In the present document, the expression "thermal substance" refers without distinction to a single thermal substance or to a mixture of different thermal substances.

In one particular embodiment of the thermal cushion according to the invention, the blocks comprise cells inside which the thermal substance is held. This embodiment of the thermal cushion according to the invention is especially well suited to the case where the thermal substance of the blocks is not solid at normal temperature of use or in normal conditions of handling for the thermal cushion. In this embodiment of the cushion according to the invention, the outer shape of the cells must meet the above-mentioned shape requirements with regard to the blocks. The choice of the substance for the cells is determined by the need for said cells to be chemically inert relative to the thermal substance that they comprise and relative to the chemical and thermal environment during their normal use. The cells must also have mechanical properties that are compatible with the mechanical stresses to which the cushion is normally subjected at normal temperature of use or in the course of handling and they must be more or less incapable of deformation (they must be made of

a rigid or semi-rigid material and of a suitable shape). In this particular case, each cell may be entirely isolated from the neighbouring cells or, as a variant, the cells may be in contact with each other so as to allow the fluid content of said cells to circulate between them. In the case where the thermal substance of the cushion is liquid or gaseous, the walls of the cells are usually impermeable to liquids or gases. Plastic materials are generally suitable for making up the cells. Useful plastic materials include polyolefins, in particular polymers and copolymers of ethylene and propylene, chlorinated polymers, especially vinyl chloride and vinylidene chloride polymers and copolymers, styrene-ethylene-butyl-styrene copolymers and polyurethane. Polyethylene, polypropylene, vinyl polychloride and styrene-ethylene-butyl-styrene copolymers are suitable in most applications. As a variant, the cells may also be made of metal, for example by drawing sheets of malleable metal or alloy such as aluminium and aluminium alloys. According to another variant, the cells or some of them are formed from composite materials: one part of the cell is made of one material and another part of the cell is made of another material. According to an additional variant, one part of the network of cells is made of one material and another part of the network of cells is made of another material.

Any known forming method may be used to produce the network of cells. The methods of casting, pressing, drawing and injection are suitable.

According to a suitable method, a corrugated sheet of a plastic or metal material is formed, which thus has a network of holes or half-cells. Another sheet is then glued or welded onto the corrugated sheet so as to block the holes of the corrugated sheet and to form the cells. This other sheet may be a corrugated or a flat sheet.

In one preferred embodiment of the invention, the thermal substance of the blocks comprises a substance that undergoes a change of state at normal temperature of use. In this embodiment of the invention, the expression "change of state" is considered in its general sense and covers any physical and/or chemical change of the substance, occurring at a more or less constant temperature and characterised in the latent heat of the change of state. Depending on the substance used, the change of state may in particular comprise the fusion of a solid, solidification of a liquid, vaporisation of a liquid, condensation of a gas, total or partial hydration of a salt, total or partial dehydration of a salt, crystallisation of an amorphous solid or recrystallisation of an allotropic form of a crystal into another allotropic form. In this embodiment of the invention, the thermal substance of the blocks may be entirely made of said substance that undergoes a change of state at normal temperature of use. As a variant, the thermal substance of the blocks may also comprise other substances or materials that do not undergo a change of state at normal temperature of use. Then, in order to avoid overburdening the text to no purpose, it will be assumed that it is the entire thermal substance that undergoes a change of state at normal temperature of use. It is in any event clearly understood that, as explained above, the invention does not exclude the case in which only a part of the thermal substance of the blocks undergoes a change of state (in the event, when it is made of a mixture of several chemical compounds of which only one undergoes a change of state at normal temperature of use or when an additional material is incorporated which is not involved in the thermal function of the thermal cushion, for example a magnet).

In the above-defined preferred embodiment, the change of state undergone by the thermal substance of the blocks at normal temperature of use corresponds to a heat absorption by

said material in the case of a cryogenic cushion and to the emission of heat in the case of a calorific cushion. In the case of an isothermic cushion, the change of state undergone by the thermal substance of the blocks at normal temperature of use corresponds to a heat absorption by said thermal substance when said normal temperature of use (which is also that of the body for which the cushion is intended) is lower than that of the surrounding environment. The change of state corresponds to an emission of heat by the thermal substance when the normal temperature of use is higher than that of the surrounding environment.

In order to use a thermal cushion true to the preferred embodiment that has just been described, the state of the thermal substance of the blocks should be suitably selected. In the case where the cushion is used as a cryogenic cushion, it is necessary first of all to bring the thermal substance of the blocks to a state which, at normal temperature of use, will undergo a change of state corresponding to a heat absorption (for example the fusion of a solid or the vaporisation of a liquid). In the case where the cushion is used as a calorific cushion, it is first necessary to bring the thermal substance of the blocks to a state which, at normal temperature of use, will undergo a change of state corresponding to a heat production (for example the solidification or crystallisation of a liquid or the condensation of a gas). In the case where the cushion is used as an isothermic cushion, in a surrounding environment at a temperature that is higher than the normal temperature of use, it is first necessary to bring the thermal substance of the blocks to a state which, at normal temperature of use, will undergo a change of state corresponding to a heat absorption (for example the fusion of a solid or the vaporisation of a liquid). In the case where the cushion is used as an isothermic cushion, in a surrounding environment at

a temperature that is lower than the normal temperature of use, it is first necessary to bring the thermal substance of the cells to a state which, at normal temperature of use, will undergo a change of state corresponding to a heat production (for example the solidification or crystallisation of a liquid or the condensation of a gas). Moreover, all other things being equal in the preferred embodiment that has just been described, the best results are obtained with thermal substances which, at normal temperature of use, have a high latent heat of change of state.

In the preferred embodiment that has just been described, the thermal substance of the blocks undergoing a change of state at normal temperature of use may be a pure body. As a variant, it may be a chemical composition that is congruent to said normal temperature of use so that the change of state occurs at a more or less constant temperature.

In the preferred above-described embodiment and its implementation variants, the choice of thermal substance for the blocks depends on the normal temperature of use of the cushion. This is itself dependent on the application for which the thermal cushion is intended. Water and aqueous solutions are normally suitable in the particular case of a cryogenic cushion intended for therapeutic applications. Pure water is suitable in the case of applications where the normal temperature of use of the cushion is close to 273K (0°C). For applications where the normal temperature of use is lower than 273K, aqueous solutions are recommended in which the dissolved body and its concentration are selected depending on the normal temperature of use of the cryogenic cushion. It is recommended that the dissolved body and its concentration are selected in such a way that partial or total precipitation of said dissolved body is avoided at the normal temperature of use of the cushion. Examples of dissolved bodies include

sodium chloride, calcium chloride, sodium carbonate, propylene glycol, glycerine, ethyl alcohol and propyl alcohol.

As explained above, when the thermal substance of the blocks is liquid, it is enclosed in cells whose walls are generally impermeable to liquids. When a liquid thermal substance that undergoes vaporisation at normal temperature of use is used, it may turn out advantageous to use, for the cells, walls with oriented permeability or walls that are impermeable to the liquid phase of the thermal substance but permeable to its gaseous phase (for example impermeable/breathable PU). However, the invention is not limited to this embodiment and it also covers the case where the walls of the cells are impermeable to the liquid phase and to the gaseous phase of the thermal substance of the cells.

In the thermal cushion according to the invention, the thermal substance of the blocks forms the main active element of the cushion and gives it its thermal properties (cryogenic, calorific or isothermic properties, depending on the intended use).

The thermal substance of the interstices has the function of increasing the effectiveness of the cushion by increasing its active surface and its active volume. The thermal substance of the interstices must have thermal properties that are analogous to those mentioned above for the thermal substance of the blocks. Its thermal properties must therefore be adapted to the intended purpose of the cushion, to its normal temperature of use, to the temperature of the body for which the cushion is intended and to the ambient temperature. As regards the thermal properties of the thermal substance of the interstices, what was explained above for the thermal substance of the blocks may therefore be repeated.

The thermal substance of the interstices must also be deformable. This additional property of the thermal substance of the interstices is necessary to allow the movement of the

articulated blocks and the deformation of the cushion. The choice of the thermal substance of the interstices and/or its implementation are therefore dependent on the structural parameters of the cushion such as the shape of the blocks, the shape of the interstices separating the blocks, the articulations of the blocks and the positions of these articulations in the network of the blocks.

In a particular embodiment of the thermal cushion according to the invention, the thermal substance of the interstices comprises an elastic, solid body. This may for example comprise foam in synthetic polymer or an elastomer, for example a natural or synthetic rubber. In the case of foam, it may be of a type with open pores or of a type with closed pores. In the case of foam with closed pores, these pores may be filled by a gas with a coefficient of heat transmission that is lower than that of air, for example nitrogen or argon.

In another embodiment of the thermal cushion according to the invention, the thermal substance of the interstices comprises a fluid. The fluid may comprise a liquid, a gas, a gel (or viscous fluid) or a solid in the form of crumbly particles (for example a powder). In this embodiment of the invention, the interstices must be sealed so as to retain the thermal substance. The sealing means used should not be an obstacle to the movement of the blocks on their articulations. Additional information concerning the sealing means of the interstices will be provided later on.

In the thermal cushion according to the invention, the interstices may be partially or completely filled by the thermal substance. It is preferable for the interstices of the network of blocks to be completely filled with the thermal substance.

Depending on the applications for which the thermal cushion according to the invention is intended, substances

capable of reflecting infrared radiation or ultraviolet radiation may possibly be incorporated into the thermal substances of the blocks and the interstices and/or, where relevant, to the membranes or envelopes. Examples of such reflective substances include in particular aluminium powders. Similarly, for other particular applications, substances capable of absorbing infrared radiation such as for instance carbon powder may be advantageously incorporated into the thermal substances and/or, where relevant, into the membranes or envelopes.

In the thermal cushion according to the invention, the interstices between the blocks may be open. This embodiment of the invention is suitable when the deformable thermal substance of the interstices is a deformable solid (for example foam) at normal temperature of use and in normal handling conditions for the thermal cushion. Alternatively the interstices between the blocks may be sealed by a sealing means. This alternative is necessary in the case where the thermal substance of the interstices is a fluid (as defined above) in normal conditions of use and of handling for the thermal cushion. It is also suitable in the case where the thermal substance of the interstices is a deformable solid body. As mentioned above, it is appropriate to choose a sealing means that does not form an obstacle to the movement of the articulated blocks.

The thermal cushion according to the invention is characterised by the design of the articulations of the blocks. It is characterised in particular by an original selection of said articulations, associated to a selection of the thermal substance of the interstices, sothat the network of blocks may undergo deformations in the three spatial dimensions, by stretching, twisting and rotation.

As a result, according to a first implementation of the invention, the articulations of the blocks comprise

elastic solid bodies that are attached to the blocks and therefore constitute at least a part of the thermal substance of the interstices. Information concerning the elastic solid body was given above.

In this first implementation of the invention, the attachment of the elastic solid body to the blocks may be achieved by any appropriate means, for example gluing, welding or by means of screws or pegs (non-exhaustive list).

In a second implementation of the invention, the articulations of the blocks comprise elastic membranes that are attached to the blocks and put under tension in such a way as to compress a deformable body, present in the interstices, said deformable body thus forming at least a part of the deformable thermal substance. The deformable body may be an elastic solid body or a fluid. In the case of a fluid, it may be an incompressible fluid or a compressible fluid. Information concerning the elastic solid bodies and the fluids was given above.

In this implementation of the invention, each interstice may be covered by an individual membrane. The membranes are therefore appropriately attached to the blocks so as to allow them to be put under tension. Any appropriate means may be used, for example gluing or welding. The attachment of the membranes to the blocks must be sealed when the thermal substance of the interstices is fluid (gas or liquid). In a particular variant of the above-mentioned second implementation of the invention, an impermeable and elastic sheet covers at least a part of or the entire network of blocks and it therefore substitutes for the individual membranes sealing the interstices. In another particular variant of the above-mentioned second implementation of the invention, the network of blocks is enclosed in a sealed and elastic envelope. In this other variant, the envelope may be appropriately attached to the blocks in order to block the

interstices so that they are sealed when the thermal substance of the interstices is fluid (gas or liquid). In the case where the thermal substance of the interstices is a deformable solid (for example foam or elastomer), the envelope may equally be attached to all the blocks in the network of blocks, to some of them (and not to others) or not be attached to any block. The attachment of the envelope to the blocks may be achieved by any appropriate means. Appropriate means include gluing and welding. The envelope may be simple or it may comprise a complex film or it may comprise several layers linked to each other or not. It may be of different composition depending on each face. It may have treatments and additives that give it specific active properties depending on the use. It may comprise intake/outlet tubes for the introduction or the circulation of the thermal substance of the interstices when it is a fluid.

In a third implementation of the invention, the interstices between the blocks comprise a fluid and the articulations are permeable to said fluid. In this implementation of the invention, the fluid may comprise a liquid, a gas, a gel or a solid in the form of crumbly particles (for example a powder) and it forms at least a part of the deformable thermal substance of the interstices. Information concerning the fluid of the interstices was given above. In this third implementation of the invention, the selection of the articulations will depend on the state of the fluid present in the interstices. Said articulations may for example comprise flexible membranes (possibly elastic) that are porous to gases or liquids, flexible and perforated partitions, lattices, hinges with perforations or any other articulation not likely to hinder the free circulation of the fluid present in the interstices.

Depending on the type of deformable thermal substance present in the interstices, the cushion according to the

invention may associate several types of articulation, for example elastic solid bodies attached to the blocks, pivots and membranes. As a variant, in additional to the articulations, the blocks of the network may be linked to each other by rigid lugs whose mechanical resistance to bending is low and controlled. In this variant of the invention, the rigid lugs serve to give rigidity to the cushion and to make it easier to handle and they break when the cushion is applied to the body and deformed.

The thermal cushion according to the invention has the advantageous property of combining excellent heat storage and thermal exchange properties with excellent flexibility/elasticity that allows it to immediately adapt to the form of a physical body to which it is being applied in such a way that it perfectly fits the form of this body and therefore ensures homogeneous regulation of the temperature or of the heat exchanges over the whole covered surface of said body. Due to the design and structure of the thermal cushion according to the invention, its thickness has no effect on its flexibility and its ability to be deformed. In other words, the invention allows to adapt the thickness of the cushion to the desired thermal properties (to its thermal capacity) without adversely affecting its flexibility or its ability to easily adapt to various body shapes.

In another particular embodiment of the thermal cushion according to the invention, the network of blocks bears, on at least a part of its surface, a sealed and elastic envelope, generally provided with a device for the intake and outlet of a fluid (for example a gas). In this embodiment of the invention, the envelope is intended to be brought into contact with the above-mentioned physical body, with which a heat exchange must occur. By introducing a defined volume of a suitable fluid (normally air) into the envelope, it is

possible to control the heat transfer between the thermal cushion and the physical body.

In the thermal cushion according to the invention, the network of blocks may be arranged in a single layer. As a variant, the network of blocks may be formed by the superposition of several layers. The layer or the assembly of layers may advantageously be held as a sandwich between two sealed and elastic envelopes, usually being each provided with an intake and outlet device for a fluid (for example a gas). In this embodiment of the invention, one of the envelopes therefore serves, by resting on an appropriate support (for example a bandage or a shell), to apply the thermal cushion onto the body with a defined pressure. The other envelope serves to control the heat transfer between the thermal substances and the body, as explained above.

The thermal cushion according to the invention has numerous applications. It can be used in particular as an isothermic cushion (or thermostat) to maintain the temperature of containers such as bottles or thermostatic flasks. Such use of the thermal cushion according to the invention has applications in the industry for maintaining chemical products at predefined temperatures as well as in the food sector for heating, cooling and maintaining the temperature of chambers for food products.

The thermal cushion according to the invention also has applications as a cryogenic cushion, in particular in the chemical or pharmaceutical industry for keeping chemical products at low temperatures as well as in the food industry for preserving food products.

Because of its form-fitting and deformable nature, the thermal cushion is particularly suitable for applications associated with wellbeing both in the form of articles of clothing and various healthcare articles (for example compresses, masks, massage tools).

Because of its excellent ability to deformation, the thermal cushion according to the invention is especially adapted to medical, paramedical and sports applications, in particular for thermal regulation and cryotherapy. Cryotherapy is a medical technique that is widely used, especially for relieving pain (for example headaches, migraines, toothaches, muscular or inflammatory pains) so as to aid the resorption of hematomas or edemas and the healing of accidental or surgical wounds.

The invention therefore also relates to a device comprising a thermal cushion according to the invention for the therapeutic treatment of human or animal bodies.

In the device according to the invention, the cushion and its network of blocks are adapted to the method of treatment or depending on the part of the human or animal body for which said device is intended.

In a particular embodiment of the device according to the invention, the cushion is placed inside a rigid shell. In this embodiment of the device according to the invention, the shell is normally adapted to the part of the human or animal body to which the thermal cushion must be applied. It has, for example, the form of an elbow, a knee, a finger, a foot or a skull.

In this embodiment of the device according to the invention, the shell may be formed of two or several articulated elements to make it easier to put it on the human or animal body. This embodiment of the device according to the invention is especially recommended if the device is intended to be applied to the head of a person or of an animal.

In an advantageous variant of the embodiment that has just been described, a sealed and elastic envelope is inserted between the shell and the network of blocks of the cushion and this envelope is usually provided with an intake and outlet device for a fluid. This variant of the invention achieves

homogeneous application of the thermal cushion over the human and animal body. It also allows the application of the thermal cushion to the human or animal body with a defined pressure, regulated by the pressure of the fluid allowed into the envelope.

In another variant of the embodiment described above, a panel is articulated to the shell and sized in such a way that it can form, together with the shell, a hermetic chamber comprising the thermal cushion. In this variant of the device according to the invention, the thermal cushion and the shell form an integral part of a hermetic case used for handling the device. By using a panel that is suitably insulated, the device thus designed allows to maintain predetermined thermal properties. In this way, the device is especially well suited for use in the case of an emergency outside of a hospital, for example on the public highway. In the above-mentioned variant of the device according to the invention, the shell and the articulated panel may be provided with medical instrumentation with for example thermometers or tensiometers. It may also be provided with an independent device for generating heat or cold during the handling of the device, in particular during its transportation or storage.

The invention also relates to a thermal wall comprising an assembly of thermal cushions according to the invention, between two partitions or between a partition and a body. The thermal wall may be a calorific wall, a cryogenic wall or an isostatic wall, depending on whether the thermal cushions collected between its two partitions are calorific cushions, cryogenic cushions or isostatic cushions.

The thermal wall according to the invention may for example form the wall of a thermos.

In the thermal wall according to the invention, thermal cushions are preferably used in which the network of blocks is arranged in an envelope filled with a deformable

thermal substance. At least a part of the thermal substance of the envelope may comprise the thermal substance of the interstices.

Short description of the figures

Special features and details of the invention will be made clearer in the following description of the attached figures which show some particular embodiments of the invention.

Figure 1 is a schematic view in cross-section of a particular embodiment of the thermal cushion according to the invention;

Figure 2 shows a perspective view, with partial cutaway, of a detail of the thermal cushion of Fig. 1;

Figure 3 shows a detailed perspective view of Fig. 2;

Figure 4 shows, in horizontal section, another embodiment of the thermal cushion according to the invention;

Figure 5 shows the thermal cushion of Fig. 4 in vertical section;

Figure 6 shows a perspective view of a particular embodiment of the device according to the invention;

Figure 7 is a side view, with partial cutaway, of another embodiment of the device according to the invention;

Figure 8 is a back view of the device of Fig. 7;

Figure 9 is a sketch, in cross-section, of a third embodiment of the device according to the invention;

Figure 10 shows in vertical cross-section a thermal wall according to the invention;

Figure 11 shows a thermal cushion according to the invention that can be used in the thermal wall of Fig. 10; and

Figure 12 shows another thermal cushion according to the invention that can be used in the thermal wall of Fig. 10.

The figures are not drawn to scale.

The same reference numbers generally refer to the same elements.

Detailed description of particular embodiments

The thermal cushion shown in Fig. 1 and 2 comprises a network of blocks 1, formed by hollow cells. The blocks or cells 1 have the shape of prisms with square bases. Each cell 1 is formed by two truncated pyramids 3 and 4, attached along their long square bases. The side ridges of the two truncated pyramids have bevelled edges (2). The network of cells 1 is formed by the assembly of two corrugated sheets 5 in a flexible polymer material (for example in plastified polyvinyl chloride or in styrene-ethylene-butyl-styrene copolymer) pre-drawn and welded to each other along tongues 6 between the cells (a corrugated sheet 5 is shown in Fig. 3). The tongues 6 are flexible and elastic and they act as articulations between the cells 1. They are pierced by apertures 9 whose function will be explained later on. By bending or twisting the assembly of sheets 5, the cushion of cells may thus adopt complex profiles to fit an appropriate body, for example part of the anatomy of a human being or of an animal.

The thermal cushion of Fig. 1 to 3 is a cryogenic cushion intended for use in cryotherapy. To this end, the cells 1 are filled with a suitable thermal substance whose definition was given above. The thermal substance is advantageously an aqueous solution with a freezing point that is congruent and occurs at a temperature corresponding to the temperature at which the cushion is intended (normal temperature of use). When the normal temperature of use is close to 273K (or 0°C), the aqueous solution may be replaced by distilled or mineral water.

The interstices 8 defined between the cells 1 and the tongues 6 are filled with a deformable thermal substance 10 (shown in Fig. 1 only). The thermal substance 10 shown in Fig.

1 is an elastic solid body, for example a solid mass made of elastomer or polymer foam. It is preferably selected so as to have a high specific heat at normal temperature of use.

A flexible and elastic envelope 7 surrounds the network of cells 1 and interstices 8. The elastic envelope 7 is for instance a film of styrene-ethylene-butyl-styrene copolymer.

Before using the thermal cushion of Fig. 1 to 3 in a therapeutic application, it is maintained, for instance in a cool store, at a temperature low enough to freeze the aqueous solution of the cells 1. The thermal cushion is taken out of the cool store when it is about to be used and it can be immediately applied to a part of the human body that is to be subjected to cryogenic therapy, for example a hand, the head or an arm. Due to the flexibility of the envelope 7 and tongues 6 and to the elasticity of the thermal substance 10 contained in the interstices 8, the cushion deforms and perfectly adapts to the morphology of the human body.

In a modified embodiment of the thermal cushion of Fig. 1 to 3, the elastic envelope 7 is welded to the cells 1 and put under tension so that the elastic solid body 10 of the interstices 8 is maintained in a state of elastic compression in these interstices 8.

When the thermal cushion shown in Fig. 1 to 3 is used for a medical therapy, a compress can be inserted between the thermal cushion and the anatomical part of the human body. Any compress usually used in medical therapy is suitable. It may for example comprise a gauze. After the thermal cushion is placed on the compress, it is firmly attached to the part of the body to be treated by means of a bandage (adhesive or otherwise) so that when it deforms, it perfectly fits the entire part of the body to be treated. As a variant, the cushion may itself be provided with medical adhesive parts of

a repositionable type. In this particular case, the bandage is not required.

In order to improve the thermal action of the cushion on the anatomical part treated, a second thermal cushion may be advantageously placed on the first thermal cushion. In this case, only the first thermal cushion [the one directly applied to the human body (or to the compress)] is put in the cool store, the other thermal cushion being maintained at ambient temperature. In this application, the second thermal cushion may act as a thermal insulator. It may in particular act as an insulating bandage for attachment and/or compression. It may be provided with an inflatable pocket for optimum application to concave body forms.

In some embodiments, the cushion may combine in a single item the thermal function and the function of an insulating bandage and may comprise the above-mentioned compress that is inserted between the thermal cushion and the anatomical part of the human body.

In a modified embodiment of the thermal cushion of Fig. 1 to 3, the tongues 6 are pierced by apertures 9 (whose function will be explained later) and the thermal substance 10 of the interstices 8 is in a liquid or gel state at normal temperature of use. In this embodiment of the cushion, the envelope 7 is attached to the cells 1 so as to hermetically seal the interstices 8. The apertures 9 have the function of allowing the circulation of the fluid thermal substance in the network of interstices 8 when the cushion is subjected to deformation.

The structure of the thermal cushion possibly allows its use by circulation of fluid in the interstices and/or cells (connected by filling/circulation channels).

Reactions of thermogenic/cryogenic mixtures may be used to initiate the thermal function independently or to

extend the duration of the action without requiring the cushion to be removed and recharged.

The cushion may comprise elements for the control and regulation of the temperature.

In the embodiment shown in Fig. 4 and 5, the cushion comprises a network of cells 1 between which a network of an elastic solid mass 10 is inserted. The elastic solid mass 10 is for example a solid mass of elastomer or a foam of polymer resin. The elastic network 10 is attached to the network of cells 1 by gluing or welding. The elastic network 10 also acts as an articulation between the cells 1.

Fig. 6 shows the use of the thermal cushion according to the invention in a device for the therapeutic treatment of an element of the human body. The therapeutic treatment may for example be the cryogenic treatment of an arm or a thigh. To this end, the device comprises a thermal cushion referred to in its entirety by the reference number 11. The thermal cushion comprises, as explained above, a network of blocks 1 and interstices 8, comprising suitable thermal substances. The thermal cushion 11 is attached to a bandage 12 intended to attach it to a person's arm. A rectangular aperture 13 is made in the network of blocks 8. The aperture 13 serves to give access to a defined area of the arm in order to subject it to a suitable therapeutic treatment (for example to treat a wound, a contusion or another local condition there). The aperture 13 may be used to apply a dressing to the arm. As a variant, it may be filled by a small removable thermal cushion according to the invention. The thermal cushion 11 of the device of Fig. 6 may for example be a cryogenic cushion, designed to put an arm into hypothermia while the zone accessible through the aperture is subjected to a suitable therapeutic treatment.

The device of Fig. 6 may obviously be adapted to the treatment of the limb of an animal, for example a horse's leg.

Fig. 7 and 8 show a device according to the invention for the therapeutic treatment of a person's skull. The device comprises a rigid shell 14 that takes the form of a helmet closely fitting the person's head 15 and neck. The helmet 14 is made up of three articulated elements 16, 17 and 18 (Fig. 8). Element 16 serves to cover the top of the skull and elements 17 and 18 are intended to surround the neck. The inner part of the helmet 14 is shown at a larger scale in a zone marked by the reference X in Fig. 7. It comprises a thermal cushion under the shell 14. The thermal cushion is true to the invention and successively comprises an insulating layer 19, a sealed envelope 20 (whose function will be explained later on), a network 11 of articulated blocks comprising a thermal substance and a second sealed envelope 22. The sealed envelope 20 comprises a device (not shown) for injecting a fluid under pressure into it. This is usually air that is injected into the pocket by means of an electric or manual pump (of the type used for bicycles or used on medical or paramedical tensiometers). The pocket 22 is similar to the pocket 20 and is also designed for injecting a defined volume of air under pressure. When it is necessary to subject a patient's head to cryogenic treatment, for example to put it into hypothermia, the helmet 14 and its thermal cushion are maintained in a cool store for an appropriate period so that they reach a predetermined temperature. Element 16 of the helmet 14 is then applied to the top of the skull on the patient's head 15 and elements 17 and 18 are folded around the patient's neck. A defined volume of air is then injected into the pocket 20 so as to apply the network of articulated blocks 11 with a predetermined pressure onto the patient's head 15. Then, a defined volume of air is possibly injected into the pocket 22. The air pocket 22 acts to form an insulating film between the network of blocks 11 and the head 15 so as to regulate the heat flux between the head 15 and the thermal

substance of the blocks 11 of the thermal cushion. The heat flux is controlled at will by choosing an appropriate volume of air to be injected into the pocket 22. The shell 14 of the device of Fig. 7 and 8 may advantageously be provided with medical tools with for example thermometers or tensiometers.

Fig. 9 shows a variant of the embodiment of the device of Fig. 7 and 8. In the device of Fig. 9, the shell 14 has the shape of a hemisphere adapted to cover the top of a person's skull. It is made up of two elements 23 and 24 articulated on a ring 25 intended to surround the cranium at the level of the forehead. The elements 23 and 24 each have a thermal cushion according to the invention (not shown) on their inner faces. Two panels 26 and 27 are moreover articulated to the ring 25. The two panels 26 and 27 form, together with the elements 23 and 24, a chamber in which the thermal cushions of elements 23 and 24 are enclosed. The shell 14 and its thermal cushions thus form an integral part of a case (which may be hermetic and insulating) for the transportation and handling of the device. The device shown in Fig. 9 is especially well suited for emergency use outside of a hospital, for example to attend an emergency on the public highway. The shell 14 may also be provided with an independent device for generating heat or cold during the transportation of the device or its handling.

Fig. 10 shows another application of the thermal cushion according to the invention. It shows part of a cryogenic wall 28 of a thermos intended to preserve organs or cold foodstuffs. The cryogenic wall 28 comprises a pair of partitions 29 and 30 that define between them a chamber filled with small cryogenic cushions 31 according to the invention. In accordance with the invention, each cryogenic cushion 31 comprises blocks 32 (Fig. 11) connected by a flexible membrane 33 and filled with a rigid cryogenic substance, for example ice. The network of blocks 32 is enclosed in a flexible and

hermetic envelope 34 filled with a fluid cryogenic substance 35. The fluid cryogenic substance 35 may for example be a gel. The deformable nature of the cryogenic substance 35 optimises the refrigerant properties of the wall 28.

Fig. 12 shows another embodiment of the cryogenic cushions 31 that can be used in the cryogenic wall 28 of Fig. 10. In this embodiment, the cryogenic cushion comprises a chain of blocks 32 connected by pivots 33 and comprising a rigid cryogenic substance (for example ice). The chain of blocks 32 is enclosed in a tubular envelope 34 filled with a cryogenic gel 35.

By extension, the invention also relates to thermal walls in which the thermal cushions comprise a single block 32 (comprising a rigid thermal substance) in a flexible envelope comprising a fluid thermal substance [liquid, gas, gel or in the state of crumbly particles (powder)].